state can be inferred, for instance, from the quality of the interference pattern obtained from a superfluid state after a time-of-flight experiment[6]. In a three-dimensional situation, the energy increase after the ramp should depend only on the ramp speed, but not on the system size. By contrast, in one or two dimensions, the energy added per atom at a given ramp speed will increase with system size. Numerical calculations by Polkovnikov and Gritsev on a slowly driven (non-integrable) Bose–Hubbard model support these predictions in a quantitative way.

It is remarkable that even for such basic problems as the adiabatic limit, sometimes new and surprising features are found. In a different context and for classical systems, Jarzinsky[7] showed that the work done in a non-equilibrium process is directly related to the equilibrium free-energy difference between the initial and final states. This idea has been applied successfully to determine free-energy landscapes of complex molecules from unfolding experiments with an atomic force microscope[8]. The present findings of Polkovnikov and Gritsev on the limits of adiabaticity in quantum systems may open a new avenue for investigation of non-equilibrium phenomena in many-body physics. This area has become accessible with cold gases but little work has been done so far. Perhaps, as indicated in their paper, the ideas on the breakdown of adiabaticity will eventually also be of relevance in different areas, for instance the dynamics of the scalar field that drives inflation in the early-stage expansion of the universe[9].

References

1. Balian, R. *From Microphysics to Macrophysics* (Springer, Berlin, 1991).
2. Polkovnikov, A. & Gritsev, V. *Nature Phys.* **4**, 477–481 (2008).
3. Landau, L. D. & Lifshitz, E. M. *Statistical Physics* (Pergamon, Oxford, 1980).
4. Farhi, E. *et al. Science* **292**, 472–476 (2001).
5. Bloch, I., Dalibard, J. & Zwerger, W. *Rev. Mod. Phys.* (in the press); preprint at <http://arXiv.org/abs/0704.3011> (2007).
6. Greiner, M., Mandel, O., Esslinger, T., Hänsch, T. W. & Bloch, I. *Nature* **415**, 39–44 (2002).
7. Jarzinsky, C. *Phys. Rev. Lett.* **78**, 2690–2693 (1997).
8. Bustamente, C., Bryant, Z. & Smith, S. B. *Phys. Today* **54**, 46–51 (2003).
9. Mukhanov, V. *Physical Foundations of Cosmology* (Cambridge Univ. Press, Cambridge, 2005).

SUPERCONDUCTIVITY

Has lightning struck twice?

John Bardeen, who would have celebrated his 100th birthday on 23 May, was the only person to have won two Nobel prizes in physics — one for the transistor and the other for the microscopic explanation of superconductivity, known as the Bardeen–Cooper–Schrieffer theory (BCS). For about 30 years, all superconductors more or less behaved according to BCS, none of them violating the predicted 30 K maximum transition temperature T_c. However, in 1986, along came the copper-oxide-based superconductors, with T_c rapidly reaching 164 K (under pressure). According to David Pines, Bardeen was delighted, as he had proposed several (non-BCS) models for superconductivity of purely electronic origin — with spin fluctuations replacing phonons as the pairing glue — and he thought a novel mechanism had to be at work in the cuprates.

Recently, a new and unexpected family of superconductors, based on FeP or FeAs layers, has seemed to further challenge BCS. In the case of non-superconducting LaOFeAs, with alternating stacks of LaO and FeAs layers, fluorine doping into the LaO layer induces superconductivity at 26 K (ref. 1). Under pressure[2], the superconductivity survives up to 43 K. Chemically exchanging a smaller ion for La mimics applied pressure, and indeed, with Sm substitution, the transition temperature increases to 43 K (ref. 3). With further tweaking[4], $SmO_{1-x}F_xFeAs$ reaches a T_c of 55 K. Oxygen vacancies also seem to have an important role in raising T_c.

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As the rush continues to push T_c ever higher, what of the physics of these superconductors? At first sight, Fe is an unusual ingredient, as ferromagnetism and superconductivity are generally viewed as being antagonistic. Placing a superconductor in a magnetic field will kill the superconductivity eventually.

And to complicate matters, antiferromagnetic correlations are present as well. Experimental probes[5–8] detect a structural phase transition near 150 K and an antiferromagnetic transition — with long-range spin-density wave order — closer to 130 K in undoped LaOFeAs. With increasing F-doping, both of these features move to lower temperature, weakening and eventually disappearing. As superconductivity appears while the other two wane, the magnetism and superconductivity do seem to be competing states.

The similarities between these superconductors and the cuprates are suggestive, but it's too early to jump to conclusions, or say whether the FeAs family will dethrone the cuprates in terms of T_c. From Bardeen's approach to superconductivity, Pines ventures that Bardeen "would have suspected that a magnetic mechanism could be at work, but he would have wanted some direct evidence for this. After considering various experimental probes, he would likely have encouraged his colleagues to produce sufficiently pure samples that NMR experiments could look for a build-up of antiferromagnetic spin fluctuations in the normal state, analogous to that seen in the cuprates, and perhaps, as a bonus, provide a tentative identification of an unconventional pairing state. Then, he would have waited for the experimental results before embarking on detailed model calculations."

References

1. Kamihara, Y. J., Watanabe, T., Hirano, M. & Hosono, H. *J. Am. Chem. Soc.* **130,** 3296–3297 (2008).
2. Takahashi, H. *et al. Nature* **453,** 376–378 (2008).
3. Chen, X. H. *et al. Nature* doi:10.1038/nature07045 (2008).
4. Ren, Z. A. *et al.* Preprint available at <http://arxiv.org/abs/0804.2053> (2008).
5. Dong, J. *et al.* Preprint available at <http://arxiv.org/abs/0803.3426> (2008).
6. de la Cruz, C. *et al. Nature* doi: 10.1038/nature07057 (2008).
7. Kitao, S. *et al.* Preprint available at <http://arxiv.org/abs/0805.0041> (2008).
8. Klauss, H.-H. *et al.* Preprint available at <http://arxiv.org/abs/0805.0264> (2008)

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